

## BACKGROUND

- The U.S. imports > 90% of the seaweed consumed, with China, Korea, and Indonesia leading global production.
- As seaweed aquaculture develops in California, advancing food-use pathways requires species-specific post-harvest protocols that preserve quality and safety.

**Obj: We evaluated shelf-life performance, designed food-safety testing panels, and created FDA-format Nutrition Facts labels for four cultivated species to support product development and regulatory alignment for Southern California seaweed aquaculture.**



Figure 1. Port of San Diego Shellfish and Seaweed Aquaculture Program Discussion Draft, 2024.

## SPECIES BACKGROUND

<p><b>Ulva spp.</b> Sea lettuce</p> <p>Fast-growing green alga cultivated in land-based tanks. Thin blade morphology makes it handling-sensitive. High protein (4.2 g/100g) and iron content. Versatile culinary use in salads, soups, and seasonings.</p>	<p><b>Macrocystis pyrifera</b> Giant Kelp</p> <p>Brown alga of Southern California kelp forests. Nutrient-rich with high dietary fiber (6.8 g/100g) and potassium (1,451 mg/100g). Used in broths, snacks, and gourmet dishes.</p>	<p><b>Develaria mollis</b> Pacific dulse</p> <p>Red alga with a slight umami flavor, cultivated in tank systems. Notable iron content (19.7 mg/kg) and high respiration rate. Valued as a fresh snack and salad ingredient.</p>	<p><b>Gracilaria parvispora</b> Ogo</p> <p>Red alga traditionally used in Hawaiian and Asian cuisine. Low calorie (17 kcal/100g) with notable vitamin C (88 mg/kg). Sensitive to osmotic conditions during post-harvest handling.</p>
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## SHELF LIFE PERFORMANCE

Species	Storage Temp	Packages Tested	Primary Failure Mode	Best Condition (within trial)	Usable Shelf-Life
<b>Ulva spp. (Sea Lettuce)</b>	4°C	BreatheWay film, Acacia bag, Lidded clamshell	Rapid tissue breakdown + bacterial growth (holdfast region)	No clear winner; prioritize gentle handling + rapid chilling	< 5 days
<b>M. pyrifera (Giant Kelp)</b>	4°C	BreatheWay, Acacia bag, Lidded clam, Fiber clam (PE & PP liners), Uline bag	Bacterial lesions + mucilage / slime + senescence	Light MAP (moderate O <sub>2</sub> , low CO <sub>2</sub> buildup)	5-8 days
<b>G. parvispora (Ogo)</b>	4°C	Control, PAA wash, Salt spray (30 ppt), Alginate coat, BreatheWay	Purge + tissue collapse (osmotic stress); rapid quality loss	Salt spray (~30 ppt) maintained structure and odor	5 days (salt only)
<b>D. mollis (Pacific Dulse)</b>	2-6°C	Aerated control, Bags, Cleanworks (OTR-based)	Quality loss in sealed / low-O <sub>2</sub> conditions	Oxygenated refrigerated storage outperformed sealed	Varies by O <sub>2</sub> availability

Table 1. Shelf life summary of *Ulva spp.*, *M. pyrifera*, *G. parvispora* and *D. mollis*

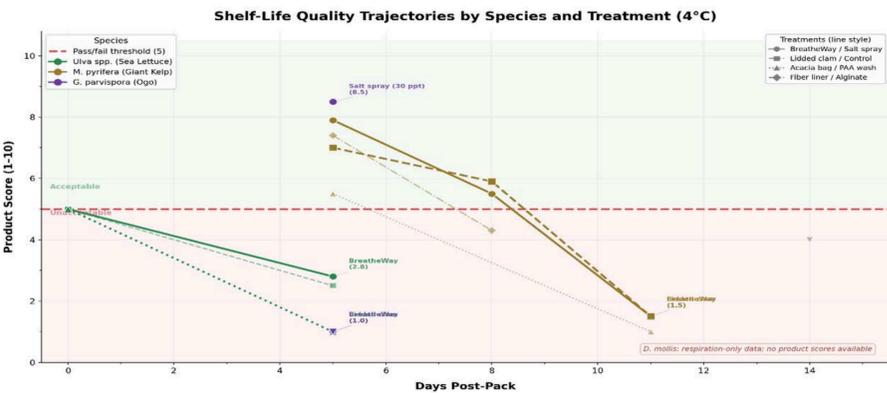


Figure 2. Shelf-life quality trajectories by species and treatment at 4°C. Scores below 5 (dashed line) indicate unacceptable quality.

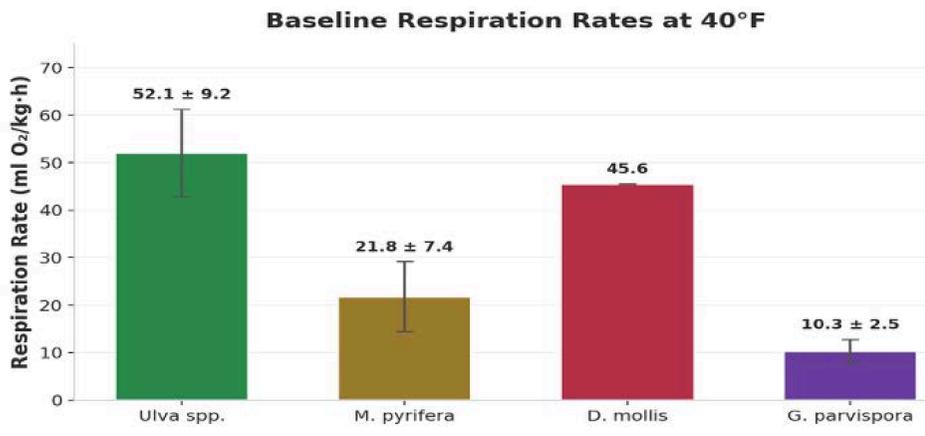


Figure 3. Baseline respiration rates (ml O<sub>2</sub>/kg-h) at 40°F. High rates (*Ulva*, *Dulse*) indicate rapid metabolic activity and faster quality loss.

## NUTRITIONAL CONTENT (FDA-FORMAT LABELING)

<p><b>Pacific Dulse (Develaria mollis)</b></p> <p>Develaria mollis is a red macroalgae species that can be found in the wild clinging to the rocky intertidal shores of the northern Atlantic and Pacific. These bushy pom-poms have a slight bitterness, clean finish, very springy when dried and rich umami smokiness when cooked.</p> <p><b>Nutrition Facts</b> Serving Size 100g Amount Per Serving <b>Calories 32</b></p>	<p><b>Ogo (Gracilaria parvispora)</b></p> <p>Ogo is a red macroalgae species that can be found in the wild clinging to the rocky intertidal shores of the northern Atlantic and Pacific. These bushy pom-poms have a slight bitterness, clean finish, very springy when dried and rich umami smokiness when cooked.</p> <p><b>Nutrition Facts</b> Serving Size 100g Amount Per Serving <b>Calories 17</b></p>	<p><b>Macrocystis pyrifera (Giant kelp)</b></p> <p>Macrocystis pyrifera is a brown macroalgae species that can be found in the wild clinging to the rocky intertidal shores of the northern Atlantic and Pacific. These bushy pom-poms have a slight bitterness, clean finish, very springy when dried and rich umami smokiness when cooked.</p> <p><b>Nutrition Facts</b> Serving Size 100g Amount Per Serving <b>Calories 48</b></p>	<p><b>Ulva spp. (Sea lettuce)</b></p> <p>Ulva spp. is a green macroalgae species that is distributed along tropical coastlines either intertidally clinging to rocky substrates, pier pilings, floating docks and even on drift wood. This flat seaweed has a very mild, slight bitterness, yet clean and refreshing. It also has a tender, delicate and soft texture when fresh, crisp, light and flakey when dried.</p> <p><b>Nutrition Facts</b> Serving Size 100g Amount Per Serving <b>Calories 50</b></p>
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Figure 3. FDA-format Nutrition Facts labels for four cultivated seaweed species, developed from extended nutritional profiling (AGQ Labs). Includes California Proposition 65 precautionary language where applicable.

## FOOD SAFETY TESTING

Table 3. Heavy metals screening across four species (wet weight basis, AGQ Labs). EU French recommendation limits shown for reference. All species below regulatory thresholds for Cd, Pb, Hg.

Heavy Metal	Ulva spp.	Ogo	Pacific Dulse	Giant Kelp	EU Limit (algae as food)
Total Arsenic (mg/kg)	0.962	0.817	1.89	12.4	N/A
Inorganic Arsenic (µg/kg)	< 20	< 20	1.463	< 300	3 mg/kg DW
Total Cadmium (mg/kg)	0.14	0.031	< 0.010	0.305	0.35 mg/kg DW
Total Lead (mg/kg)	0.022	< 0.010	0.073	0.028	5.0 mg/kg DW
Total Mercury (mg/kg)	< 0.010	< 0.010	< 0.010	< 0.010	0.1 mg/kg DW

Table 4. Microbial screening by species (AGQ Labs). All values in CFU/g.

Parameter	Ulva spp.	Giant Kelp	Pacific Dulse	Ogo	CSHPF Limit*
Aerobic Plate Count	360	< 10.0	40	10,100	≤ 100,000
Coliforms (Petrifilm)	< 10.0	< 10.0	< 10.0	< 10.0	≤ 10
E. coli	< 1.00	< 10.0	< 10.0	< 10.0	—
Salmonella spp.	Neg / 25g	Neg / 25g	Neg / 375g	Neg / 25g	Absent / 25g
Total Yeast & Mold	710	< 10.0	< 10.0	10	—

\*CSHPF = Conseil Supérieur d'Hygiène Publique de France (1990). All values in CFU/g. — = No established limit.

**Pesticide & Glyphosate Screening (AGQ Labs, all species):**  
Comprehensive residue screen (500+ compounds, GC-MS/MS & LC-MS/MS); All below LOQ (< 0.010 mg/kg) across all four species.

## CONCLUSION

Post-harvest constraints are species-specific, and integrating shelf-life optimization with standardized safety and nutritional testing provides a scalable framework for advancing cultivated seaweed as a viable food product in Southern California.